CARBON MONOXIDE EMISSIONS AND EXPOSURES ON RECREATIONAL BOATS

G. Scott Earnest, Ph.D., P.E., C.S.P.
Alan Echt, M.P.H., C.I.H.
Kevin H. Dunn, M.S., C.I.H.
Duane Hammond
Jane B. McCammon, M.S., C.I.H.*
Ronald M. Hall, M.S., C.I.H.*
Robert E. McCleery, M.S.*

Division of Applied Research and Technology

&

*Div. of Surveillance, Hazard Eval. and Field Studies National Institute for Occupational Safety and Health





This work was performed under an interagency agreement between NIOSH and the United States Coast Guard

We would also like to acknowledge the collaboration of Forever Resorts, Fun Country Marine Industries, Lake Time Houseboats, and Southeast Marine Center for access to recreational boats



Disclaimer: Mention of any company or product does not constitute endorsement by CDC, NIOSH

NIOSH EFFORTS

- NIOSH has been studying carbon monoxide (CO) poisonings on recreational boats for several years
- These efforts involve epidemiology, hazard evaluation, and engineering control work
- Initial efforts were focused on CO poisonings on houseboats; however, it became apparent that other recreational boats (ski boats, cabin cruisers, fishing boats, etc.) should be looked at as well.





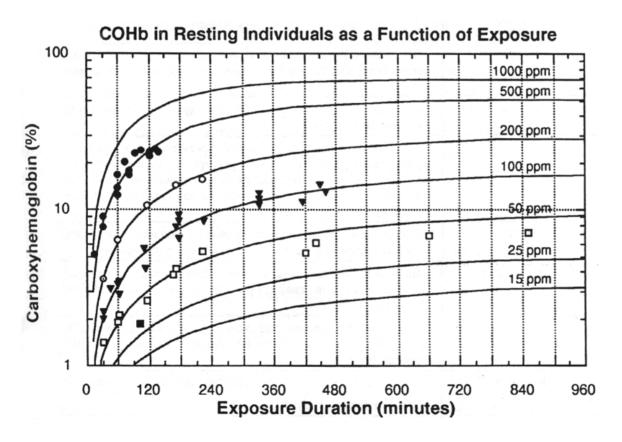
IMPORTANT QUESTIONS

- Where is it safe on my recreational boat?
- Is it safe to pull my children (grandchildren) behind the boat in a tube
- How long should the rope be?
- Is is safe to sit in the rear seat and under what conditions?





CO Concentration, COHb, and Exposure duration



Effects of COHb

0-10 None 10-20 Tension in forehead 20-30 Headache 30-40 Nausea, Vomiting 40-50 asphyxiation

50-60 Coma, Convulsions 60-70 Possible death

Uptake of Carbon Monoxide by normal resting humans. Peterson, J.E. & Stewart, R.D. (1977) Predicting the carboxyhemoglobin levels resulting from carbon monoxide exposures. J. Appl. Physiol., <u>39</u>, 633-638.

FEATURES OF EVALUATED RECREATIONAL BOATS

- Approximately 25 evaluated boats
- Ages ranged from new to 27 years old
- Boat manufacturers: Carver, Fourwinns, Formula, Polaris, OMC, SeaRay, Malibu, Glastron, Silverton, Bayliner, and Crownline
- Engine brand names: Evinrude, Bombardier, Crusader, Ford, Chevrolet, Johnson, Mercury Marine, OMC, Polaris, Pleasurecraft, Volvo Penta, Westerbeke, Kohler, Onan
- Engine types included: gasoline-powered, 2-stroke & 4-stroke, outboard, stern-drive, inboard, and generator sets





SOME OF THE EVALUATED RECREATIONAL BOATS



EVALUATION OF A MOVING RECREATIONAL BOAT







EQUIPMENT

- Ph.D. Toxilog CO sensors (1,000 ppm upper limit)
- Ultrasonic wind monitor
- Hot wire anemometer
- Exhaust gas analyzer
- Evacuated glass containers & detector tubes
- Garmin Global Positioning System





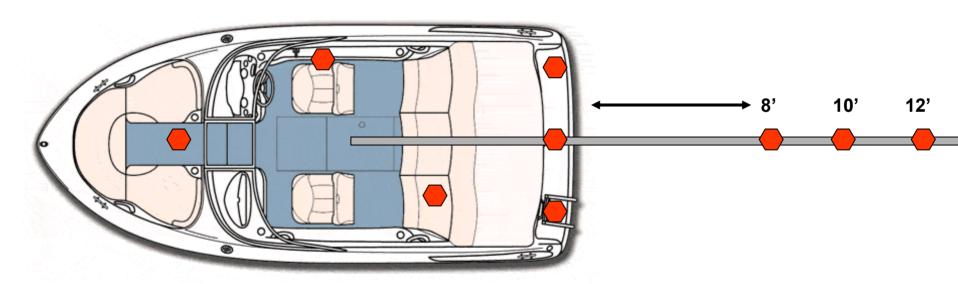
METHODS

- Evaluations typically took several hours for each boat
- CO monitors were placed at various locations on the boat and behind the boat
- Air sampling occurred while boat was stationary and moving
- While moving, boat speed and relative wind speed was measured





TYPICAL SAMPLE LOCATIONS



Not to Scale

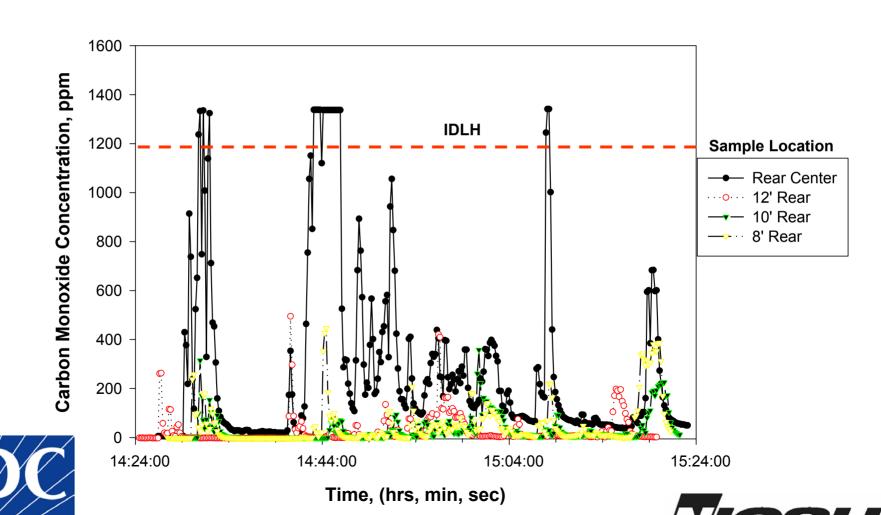




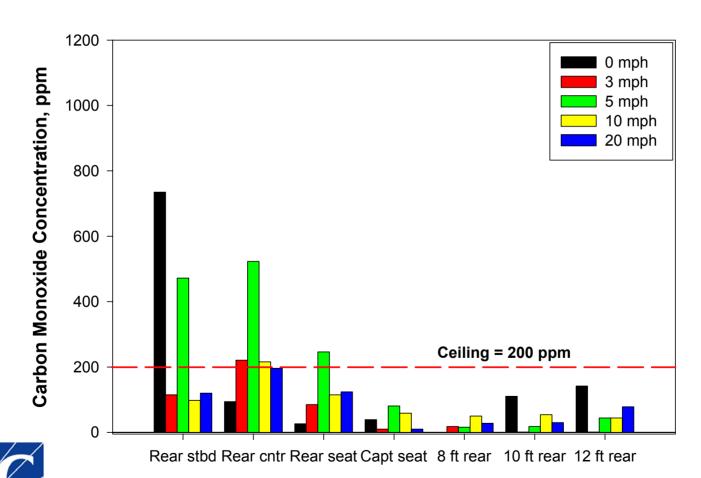


REAL-TIME CO DATA

(18' Crownline Bowrider with OMC 350 Cobra engine)



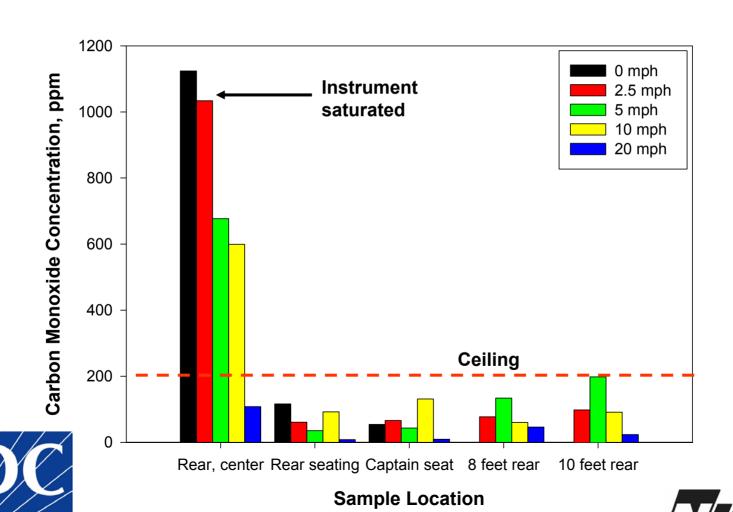
(18' Crownline Bowrider with OMC 350 Cobra engine)



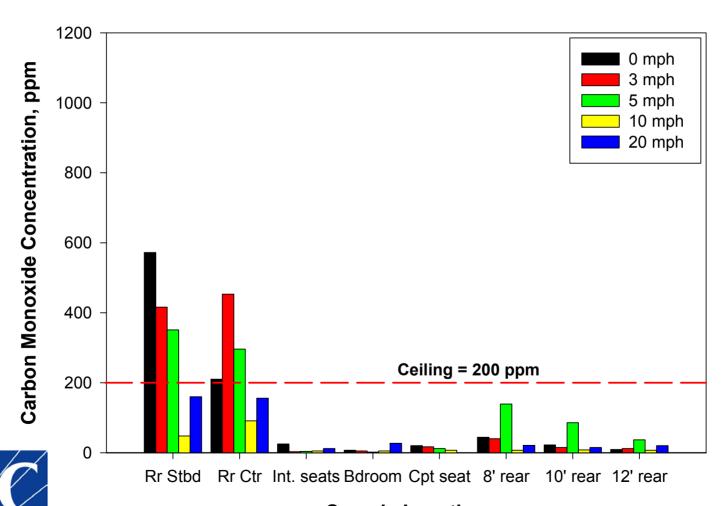




(Glastron Day Cuddy Cruiser- V8 Ford engine)

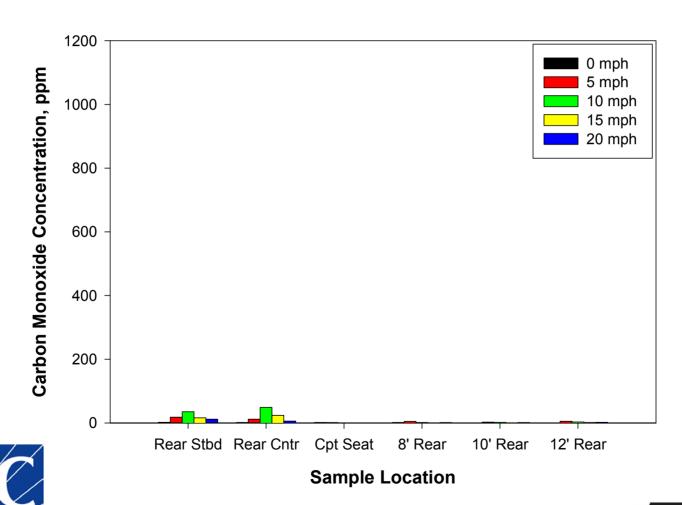


(32" Bayliner Cabin Cruiser: 2-V8 Volvo engines)





(Fourwinns 180 Horizon, 150hp Evinrude Ficht)





DISCUSSION

- Evaluation of approx. 25 rec. boats (excluding houseboats) showed that most boat drive engines and generators produced hazardous CO concentrations near the stern
- These concentrations are particularly hazardous for boats operating in a **stationary mode** (cabin cruisers) or at low speeds (< 5 mph) while boaters are *near the emission source*
- Cleaner burning engines could play an important role in reducing the CO concentrations from other rec. boats





FACTORS INFLUENCING CO EXPOSURES

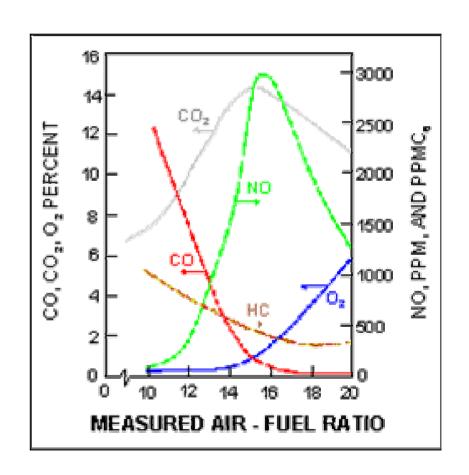
- CO generation rate
- boat design and shape
- boat speed
- wind conditions
- distance between exhaust terminus and individual's breathing zone





MANY FACTORS INFLUENCE THE CO GENERATION RATE

- Air-Fuel Ratio
- Engine design (2-stroke vs. 4-stroke)
- Engine size and flow rate
- Fuel type
- Fuel delivery (carb vs. injection)
- After treatment





EPA REGULATIONS INFLUENCE EXPOSURES

- Most EPA regulations are driven by concern for hydrocarbon and nitrous oxide emissions rather than carbon monoxide.
- There are 3 EPA regulations that relate to CO emissions from spark ignition engines on recreational boats:
 - outboard spark ignition engines
 - inboard and stern-drive engines
 - small equipment spark ignition rules (for generators)*



CONCLUSIONS & RECOMMENDATIONS

- Manufacturers, owners, and users of recreational boats should be concerned about CO poisoning potential
- The potential for engineering controls to reduce CO exposures should be investigated (exhaust configurations, ventilation, emission control)
- The issue of inadequate air supply should be more systematically investigated





CONCLUSIONS & RECOMMENDATIONS

- CO monitors could play an important role on some boats (not a primary control)
- Standard setting bodies should examine existing standards to ensure that they adequately address CO poisonings on <u>all</u> recreational boats
- Interagency educational efforts should continue



